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Study of Design for Community-based Self-help Nucleic Acid Testing System

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Abstract:

Based on the existence, relatedness, and growth (ERG) theory, this study systematically explores the needs of community-based nucleic acid testing under the normalization of the COVID-19 pandemic by investigating three communities in the Quanshan District of Xuzhou City in Jiangsu Province, China, and categorizes the shortcomings of current services into two dimensions of basic medical services and mental health services. Starting from the needs level, it is found that a community-based nucleic acid testing service structure and corresponding resources are needed, in which a structure with three levels of services is necessary. The needs and service structure elements are mapped, and this map is then used as a visualization method to balance the two. Finally, community-based nucleic acid testing service model is proposed which is used to design community-based nucleic acid testing means for the three communities discussed in this study.

Keywords*: ERG theory, nucleic acid testing, community-based medicine, grounded theory, factor analysis, COVID-19, pandemic.*

I. INTRODUCTION

This paper discusses a new concept of community-based nucleic acid testing to reduce the burden on the health care sector and facilitate quick and accurate detection of virus results, as opposed to the currently used approach of visiting a hospital, clinic or central testing site for the testing. On 11 March 2020, the World Health Organization (WHO) declared the outbreak of coronavirus disease 2019 (COVID-19) to be a pandemic. [1,2] To date, COVID-19 lingers and has become a major health threat worldwide with major impacts on healthcare delivery systems internationally. Guan et al. [3] conducted a study in 31 provinces and provincial municipalities in China and found that less than half of the patients initially had a fever from COVID-19 or 43.8%, but after hospitalization, the percentage of those who developed a fever increased to 87.9%. The patients also did not have abnormal radiological findings but the majority of those who are admitted to a hospital are immunocompromised, so they become cross-infected from other patients who are hospitalized without knowing that they have COVID-19 [3-4]. This has led to a surge in patient infections. In the United States (US), the healthcare delivery system responded by mandating staff to have adequate personal protective equipment in place, increasing the number of ventilators to help COVID-19 patients survive until they recover, and building staffing models to support a physically,

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emotionally and mentally exhausted workforce. Elective surgeries have been cancelled and clinics could not offer in-person care to prioritize patient safety and allocate resources to treat COVID-19 patients. Safety net hospitals in the US which provide healthcare for those who do not have the ability to pay are also undergoing changes. Aside from direct clinical care, some of these hospitals had acted as "community anchors prior to the pandemic, providing services such as support groups, food pharmacies, exercise classes and linkages to other resources". [5] However COVID-19 has suspended many of these face-to-face initiatives for safety reasons. Calthrope et al. [5] provided the Zuckerberg San Francisco General Hospital and Trauma Center in San Francisco as an example, which suspended services that were normally provided as they could not "fulfil the multifaceted role they had played in the community prior to the pandemic". [5]

In addition to the disruption of normal business and social activities, COVID-19 also has a direct impact on economies worldwide. In the absence of a definitive cure and emerging mutations of COVID-19 such as the Delta and Omicron variants, there are few remedies to stop spreading the virus. One of the solutions has been to mandate mass quarantine, but this is not the ideal solution, as there are severe consequences, including economic decline and social problems, which perhaps cause irreparable damage in the long run. One of the recommended ways to minimize economic repercussions is to isolate the infected, which can be done after their COVID-19 test results come back as positive. This test must be efficient enough to test a large population to screen those who need to be isolated in a short period of time.[6] The Chinese government has also stated that good prevention and control procedures in general require increase in detection capabilities and testing capacity, as well as the ability to carry out large-scale nucleic acid and antibody testing so that all key populations can be tested and all workplaces and social venues where there are gatherings for work and business purposes can have access to testing as much as possible [7]. However, the actual efficiency of testing in various countries shows that due to the large number of tests needed and the limited testing capacity of designated hospitals, clinics, pharmacies or medical facilities, many of those who are vulnerable cannot be tested in a timely manner. Moreover, those who need to provide proof of nucleic acid testing cannot have their test done in designated hospitals as they require proof of testing (negative) before they arrive.

1.1 Characteristics of normalized prevention and control measures

The normalization of prevention and control measures for COVID-19 means that this global pandemic is consistently increasing in number of infections and spreading in different areas. This normalization acknowledges that circumstances or situations that were originally sudden, uncertain and infrequent have escalated into those that are prolonged, persistent, and continuing.[8] The normalization of pandemic prevention and control requires the continuation, permanence, and longevity of prevention and control measures, as well proactive practices and strategies. This normalization is embedded and ingrained in the everyday life of a society, but prevention and control measures remain its core essence so that such measures are integrated into both daily life and work.

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1.2 Problems with existing nucleic acid testing models

With the likelihood that the COVID-19 pandemic is the new normal for a long period of time, nucleic acid testing has become one of the most important routines in everyday life and work, and the number of people tested has snowballed from hospitalized patients to those who are suspected of infection, then to close contacts and finally, to those in a community where COVID-19 is spreading rapidly, such as frontline workers in essential services, including grocery stores, or even students. Subsequently, there is an increase in the number of people who need to be tested. Nevertheless, routine nucleic acid testing for COVID-19 cannot be realized due to insufficient testing capacity, sustained workload pressure on designated hospitals, high risk of cross-infection at designated hospitals, complex processes in reporting the testing results, and inability to effectively test those who need testing on a short notice.

1.3 New nucleic acid testing model based on community health services

Liu [9] examined global community health service models, and recommended that almost all countries need to have community health institutions with different service models even though the nature of primary community health institutions already varies from country to country due to different community health models. Therefore, precedence should be given to forming prevention and control measures at the grassroots level for primary health care, build systems that enhance the service capacity of primary health institutions, and synthesize primary health service and disease prevention and control systems.[10] The President of the People's Republic of China, Xi Jinping, pointed out that "the community is the first line of joint prevention and control of pandemics, and it is also the most effective line of defense against external importation and internal spread".[11] The US also echoes this position on community based testing, specifically for COVID-19 with the Community Based Testing Sites (CBTS) program which conducted over 11 million tests at 8319 sites in the US with state and local partners, pharmacies, and different level health agencies. In the UK, the National Health Service has launched surge testing for COVID-19 at the community level where the variants have been found, which involves door to door testing through home kits and mobile testing sites. Therefore, decentralizing nucleic acid testing from designated hospitals to the community where the residents are located can effectively solve some of the shortcomings of existing testing methods. Wang et al. [12] also concluded that community medicine clinics offer comprehensive services that include disease prevention, medical treatment, health care, rehabilitation and health education with the community as the unit of care, families as the unit of change, and health as the centre.[12] Academics or health authorities in other countries have also been emphasizing on the importance of community medicine clinics. For example, reforms that combine and integrate community health centres (CHCs) with other CHCs, physician groups or hospitals have been undertaken to solve financial problems and improve the quality of services in the US[13]. Canada began to explore the use of the internet to link community health care centres especially in the rural areas, and share resources and information among them in the 1990s. [14] All of these studies contribute to a model on community-based nucleic acid testing in this study.

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II. MATERIALS AND METHODS

This study classifies the demand for nucleic acid testing in accordance with the existence, relatedness, and growth (ERG) theory proposed by Clayton Alderfer, an American psychologist and Professor of Organizational Behavior at Yale University before his passing. His work is based on a large number of empirical studies and an extension of the hierarchy of needs proposed by an American psychologist, Abraham Harold Maslow. [15] The five needs of Maslow, "physiological (food and clothing), safety (job security), love and belonging needs (friendship), esteem, and self-actualization", in which the needs at the bottom of the hierarchy must be met before the needs at the higher levels can be addressed, were recategorized into the three categories of ERG by Alderfer. In this study, the ERG theory is used to categorise need and need for community-based nucleic acid testing based on the three core needs of existence (physiological and safety-related needs), relatedness (sustaining interpersonal relationships), and growth (personal development) in conjunction with the relevant community medical and nucleic acid testing standards issued by the Chinese government.

Field research was carried out in three local communities in the Quanshan District of Xuzhou City in Jiangsu Province, China. In-depth interviews were done with residents to examine the actual demand for nucleic acid testing with the normalisation of the pandemic. We went to the community and randomly selected local residents for interview. After removing unreliable research results. In total, 50 residents were interviewed included 30 men and 20 women and they are between the ages of 15 and 70. We adopted a semi-structured interview. Each interview was 20 minutes and conducted in local community. The experiment was approved by the ethics committee of the university of the first author, and written consent was obtained from all of the participants before they took part in the study. Then, the needs were categorised and coded by using the grounded theory. The findings were used to develop a quantitative questionnaire. Finally, the data were analysed by using SPSS software.

Finally, the data obtained from the questionnaire were used to construct a service model for community self-help testing, and design the means and services related to the provision of nucleic acid testing in the community, including examining the structure of services for community nucleic acid testing, and designing a mobile service for nucleic acid testing with the normalisation of the pandemic.

2.1 Specific needs around community nucleic acid testing based on ERG theory

The ERG theory categorises human needs into three areas: existence, relatedness and growth. Based on the surveyed needs of the three communities and the needs around nucleic acid testing as found in other documents issued by the Chinese government, such as the working manual for the nucleic acid testing of COVID-19 , the needs can be summarized into five areas: a good venue for testing, adequate supply of tests, high quality and efficient tests, quality control of the testing and adequate safety procedures in place.[16,17] Therefore, the two primary needs for community nucleic acid testing are felt and real needs. The former addresses mental health needs, which is related to the need for relatedness and growth in the ERG theory, mainly including protecting privacy, rapid testing, testing that can be carried out at any time

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and an easy and user friendly process. The latter is the need for existence, which includes the real needs of basic medical services during community based nucleic acid testing, including preventing cross infections, ensuring accurate test results and avoiding a long wait time for the results. These are illustrated in Figure 1.

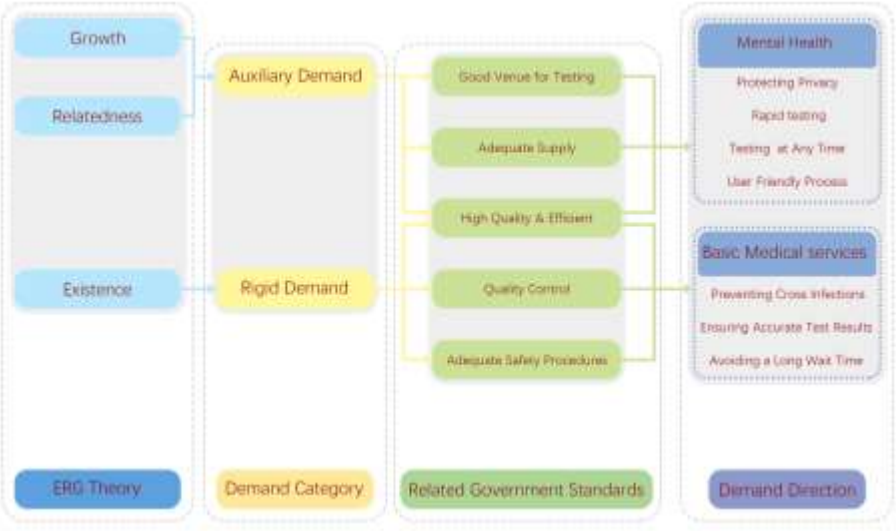

Fig 1: Studied needs based on ERG

Based on the categorized needs, interviews were conducted in the three communities of interest. About 85% of community residents believe that the current model of nucleic acid testing has unsafe factors, such as the risk of cross-infection when people gather for the testing, about 70% stated that there is room for improvement, about 75% believe that the current centralized testing at hospitals is not convenient enough, and about 65% believe that there are currently not enough testing sites which results in a long wait time.

The transcribed and mapped data from the interviews were conceptualized, coded and categorised by using the grounded theory. The first step of the grounded theory is the open coding process, in which each line of the transcripts was coded. After open coding was carried out, the information was highlighted for similarities and differences, named and compared which is the axial coding procedure, and the second step of the grounded theory. Relationships were determined among the different open codes. The third step of the grounded theory is selective coding to identify relationships among the codes and categories. The information was re-read and validated. Then, the most important domains and sub-domains were identified and a factor analysis was carried out, and used to form the model, as shown in Figure 2.

After the three cycles of coding were completed, the specific needs of community based nucleic acid testing were obtained. The real needs were classified as N1 safety procedures, including N1-1 safe, N1-2 accurate, and N1-3 controllable. The felt needs were classified as N2 high quality control of the testing, including N2-1 privacy, N2-2 comfort, N2-3 efficiency, and N2-4 convenience. These needs were taken into consideration when constructing a questionnaire in which a random sample of 50 people were surveyed. In total, 48 valid questionnaires were returned (2 were incomplete) and the data were analysed by using SPSS software. The results showed that N1-1 safe (sig.=0.002, $p<0.01$), N1-2 accurate

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(sig.=0.003, p<0.01), and N1-3 controllable (sig.=0.008, p<0.01) are statistically significant, thus indicating a high demand for safe and accurate nucleic acid testing in the community. Among the felt needs, N2-1 privacy (sig.=0.035, p<0.05), N2-2 comfort (sig.=0.048, p<0.05), N2-3 efficient (sig.=0.008, p<0.01), and N2-4 convenient (sig.=0.009, p<0.01) are statistically significant with p-values less than 0.05, as shown in Figure 3. In summary, these statistically significant real and felt needs are used to construct a model for community-based self-help nucleic acid testing services.

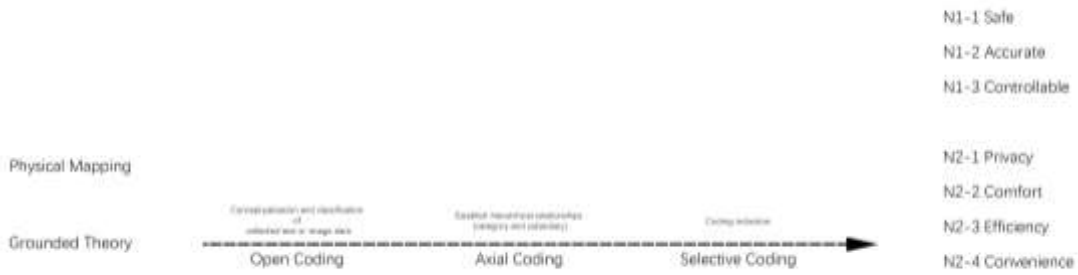

Fig 2: Three cycles of coding in grounded theory

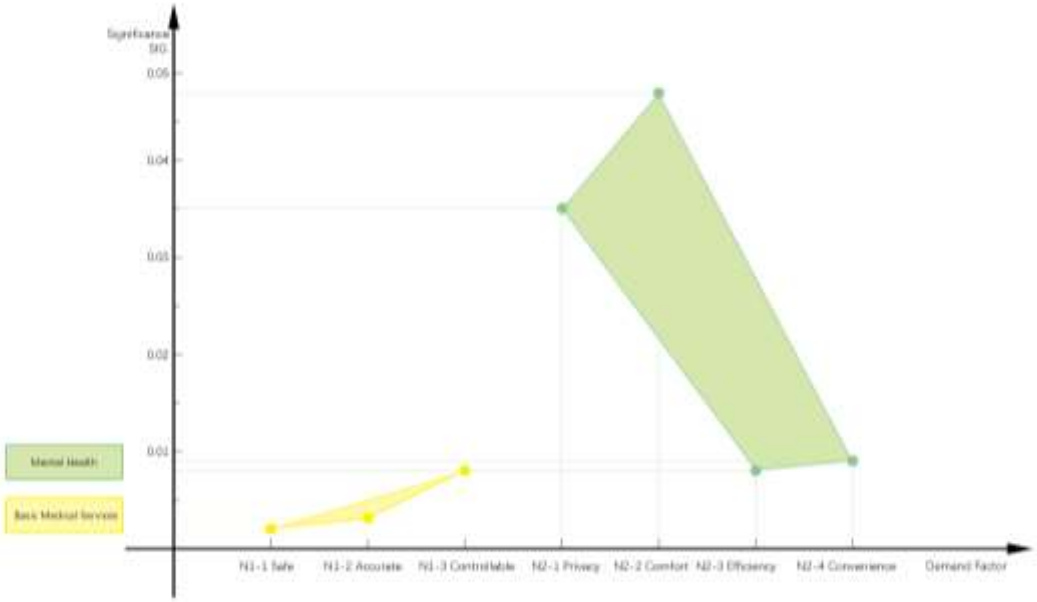

Fig 3: Specific needs for community-based self-help nucleic acid testing

2.2 Structure for service based on specific needs for community-based nucleic acid testing

Norris et al. [18] pointed out that communities have the potential to function effectively and adapt successfully after a disaster. They proposed that community adaptation is "manifested in population wellness, defined as high and non-disparate levels of mental and behavioral health, functioning and quality of life". Community resilience is mainly derived from "economic development, social capital, information

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and communication, and community competence" capacities, which as a whole, provide the means to prepare for disasters. They also proposed that to increase collective resilience, communities are advised to reduce inequities of risk and resources, involve locals in mitigating the inequities, associate with organizations, promote and protect social supports, and refrain from planning. All of these require the ability to adapt, make decisions, and reliable sources of information that work when there is much ambiguity [18]. Using the recommendations in Norris we al. [18], this study should therefore categorize the service providers of community nucleic acid testing into the following primary service providers: community service agencies, community medical and health service agencies, and community level pandemic control agencies. These agencies are then further categorized into secondary service providers and corresponding resources, as shown in Figure 4.

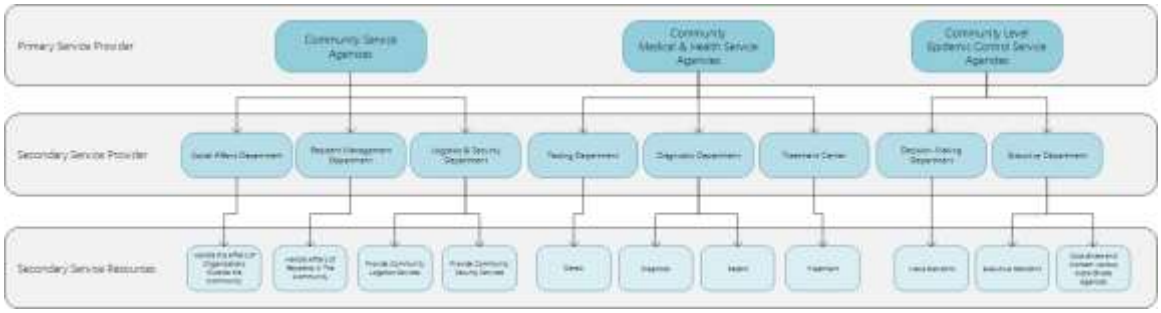

Figure 4: Community based nucleic acid testing service providers and resources

Figure 5 shows the structure of the service providers in a chart, which is categorized into three levels. The first level consists of mental health services, and basic medical services. The second level is the counseling services that fall under the mental health services in the first level, while basic support, inspection and isolation services fall under basic medical services in the first level. The services at the second level are then further subcategorized to show other resources and services: privacy and confidentiality practices (collecting, using, disclosing and storing personal information), appointment scheduling (efficient and effective), collecting services (collecting sample), disinfection services, delivery of test kits, issuing test results, providing quarantine arrangements, and treatment facilities. In practice, the structure of the services can be based on real needs.

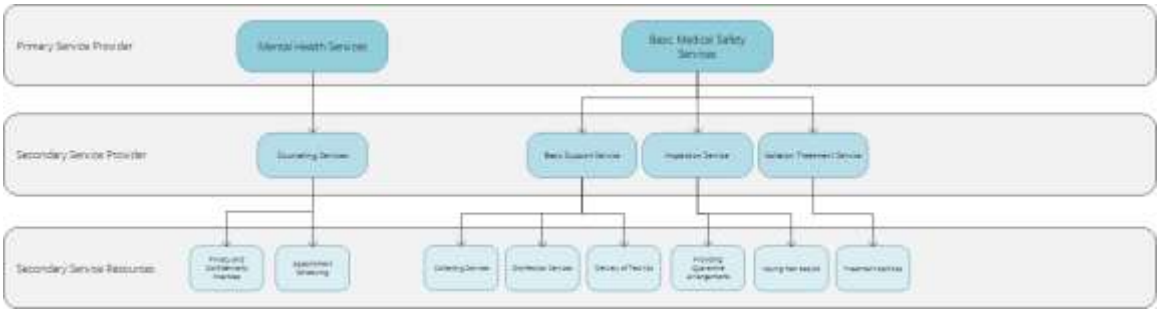

Fig 5: Structural chart of service providers

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1963-1976
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

The goal of designing services is to meet the needs of users, including instilling the notion that the services are of value, so that the interaction between the service provider and the user has value and is meaningful. The services need to take into consideration how users perceive them, and there needs to be collaboration with concerned stakeholders. Also, the services should integrate a variety of different elements and revamp the design of the original system, including how the services were carried out, the processes, and point of contact during the provision of the services, so as to enhance the experience of the users, service quality and service value. [19]

Based on the ERG theory, the needs of existence of the community residents are mainly basic medical services, while the need for growth and relatedness are considered to be mental health needs. For example, basic support, inspection and isolation services fall under basic medical services in the needs of existence. Therefore, the needs and service structure elements need to be mapped. Figure 6 used as a visualization method to balance the needs and service structure elements, i.e. by extracting the needs around nucleic acid testing and matching them with service structure elements and providing the corresponding services, and so on and so forth. When there is a mismatch between the two, or there is a structural imbalance, this will result in the shortage and even waste of allocated elements of services, i.e., the services needed or desired by community residents cannot be met well, or some of the allocated elements of services, including facilities and resources, are not fully utilized and wasted. [20]

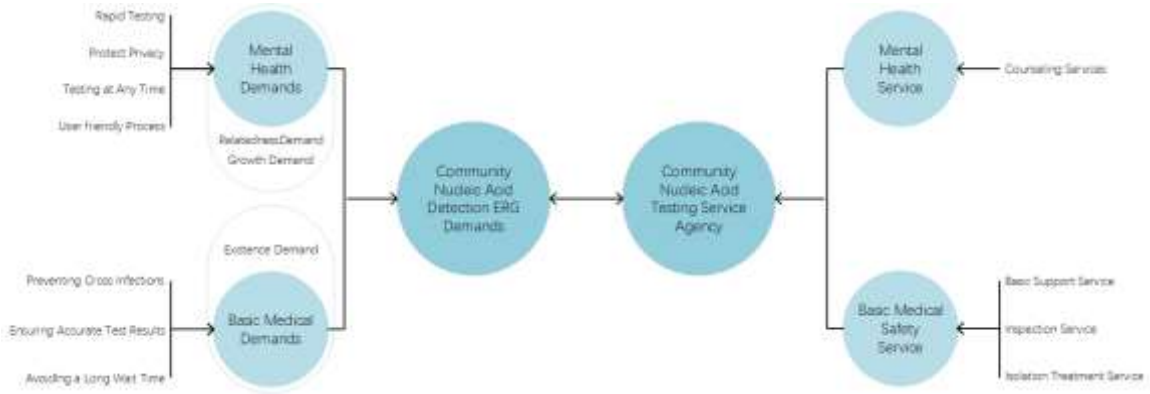

Fig 6: Mapping of needs - service structure elements

2.3 Building a model for community-based self-help nucleic acid testing services

The current plan for preventing and controlling the spread of the COVID-19 in China, as well as the need to provide medical resources at the grassroots level, relies on community medical care. The ERG theory supports the method for meeting community-based nucleic acid testing needs and the classification of the needs, as well as the effective allocation of resources by mapping the allocation of need-service structure elements, and ensuring that there is a dynamic balance between the two. The service model for community-based nucleic acid testing is constructed in Figure 7.

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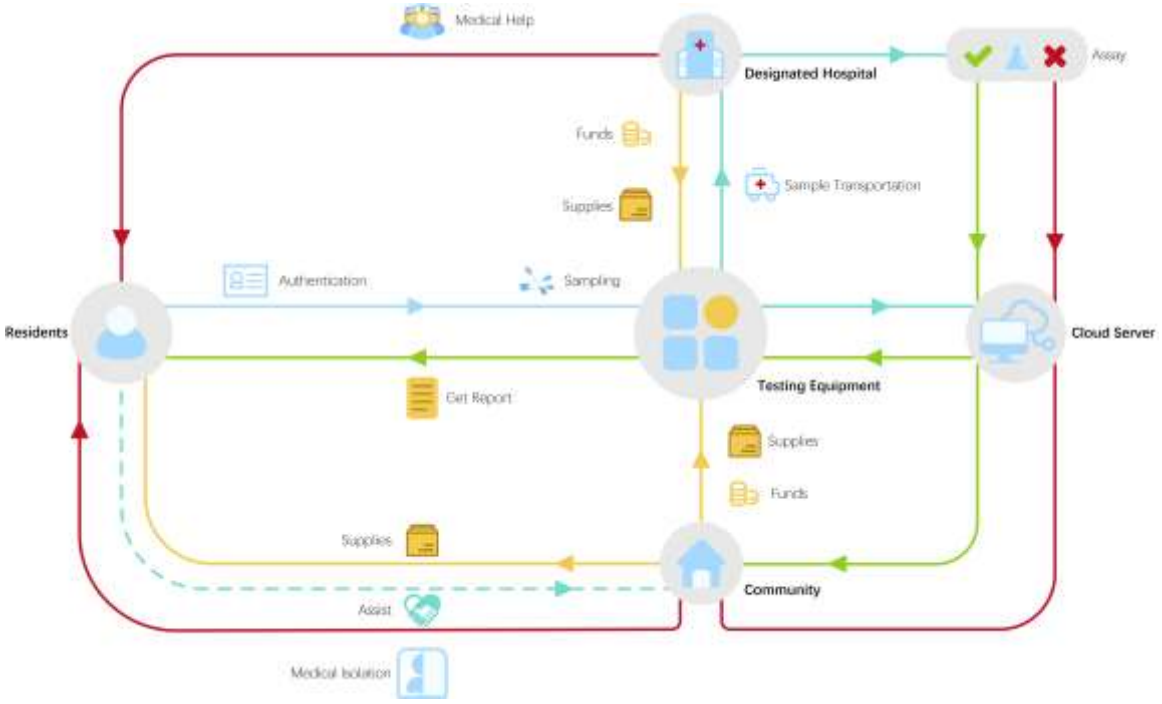

Fig 7: Community-based Nucleic Acid Testing Service Model

The community-based nucleic acid testing service model in this study has five main elements: the community residents, testing equipment, community, designated hospital and cloud server. The residents will provide proof of identity and after verification, provide a sample of their mucus from their nose or throat on site. These samples are then stored in an unmanned vehicle and transported from the test site to the designated hospital. After the hospital processes the samples, the results are uploaded onto a cloud server. The residents can then access the electronic version of their test results on a mobile phone app. This effective allocation of resources is definitive of an optimal service model which will wholly emphasize on medical services at the country level. Also, information technology is fully used to enhance tehe electronic diagnosis system, consultation, and health management and services. [21]

A smooth flow of information is necessary for effectively connecting all the internal nodes within a community-based self-help nucleic acid testing model and the effectiveness of each type of service provision. The information flow includes the verification of the identity of the tested individual and the provision of the test results to the concerned individual by the service provider, of which the acquisition and transmission of the tested information are the two most crucial elements. The acquisition and transmission of information can be done online, and efficiency of testing results acquisition and transmission can be done through mobile phones through various apps or even social media apps. For example, Alipay and Wechat can be used to verify identification as well as through QR codes.

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2.4 Physical logistics related to community-based self-help nucleic acid testing services

After examining the community-based nucleic acid testing needs and service structure elements, the objectives for designing the community-based nucleic acid testing model were obtained based on the ranking of the importance of the community's needs and the allocation of resources for community medical and hospital services, including: collection of samples such as throat and nose swabs and mouth rinse/gargle tests, overall disinfection of the testing equipment, transport of tests to a designated hospital, verification of the identity of the tested individual, collection of test reports, as well as the felt needs based on the ERG theory, which should also include protection of privacy, efficient booking of appointments, etc.

One of the most important elements of the community-based nucleic acid testing model is to have a mobile robot vehicle to serve as a point of care with built-in testing resources, sample preservation ability, and ability to deliver the tests. This unit is a robot that uses driverless technology to ensure no cross contamination and for quick set-ups between communities. Disinfection is carried out by using ultraviolet (UV) lights which are integrated and installed in the vehicle to facilitate safe and efficient disinfection to limit airborne viral transmission and sterilization of surfaces. Finally, the unmanned vehicle is functionally based according to the real needs of nucleic acid testing as per the ERG theory, see Figure 8.

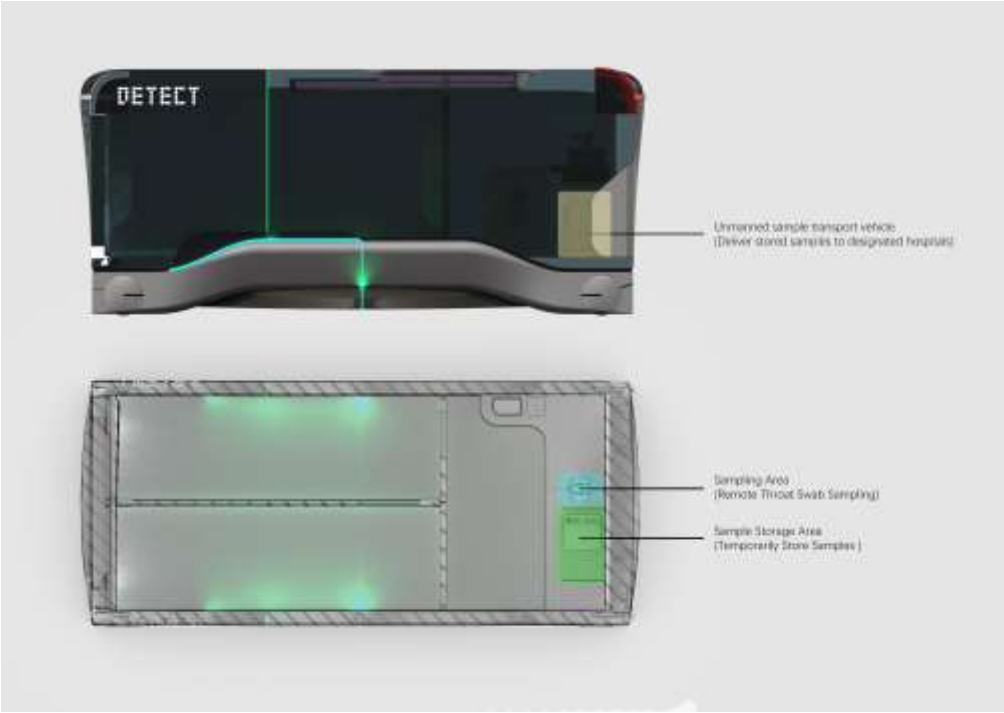

Fig. 8: Layout and functions of mobile vehicle unit

In the unmanned vehicle is an oral or nasal pharyngeal swabbing station, which not only alleviates the work fatigue or shortage of testing staff, but also has an indicator light at the top to inform the tester of the

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1963-1976
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

current availability of the station and a UV light for sterilisation on the inner side of front shaft, as shown in Figure 9.

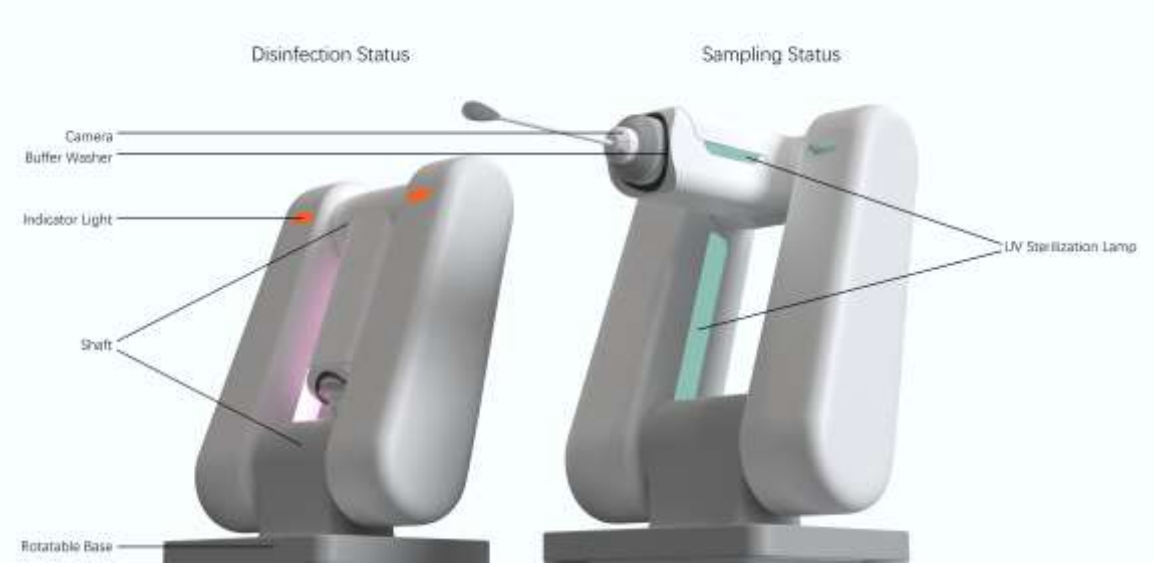

Fig. 9: Remote pharyngeal swabbing station

The mobile robot vehicle then delivers the collected tests to the nearest designated community hospital for processing the tests with no contact needed while also quickly delivering the tests for processing, as shown in Figure 10.

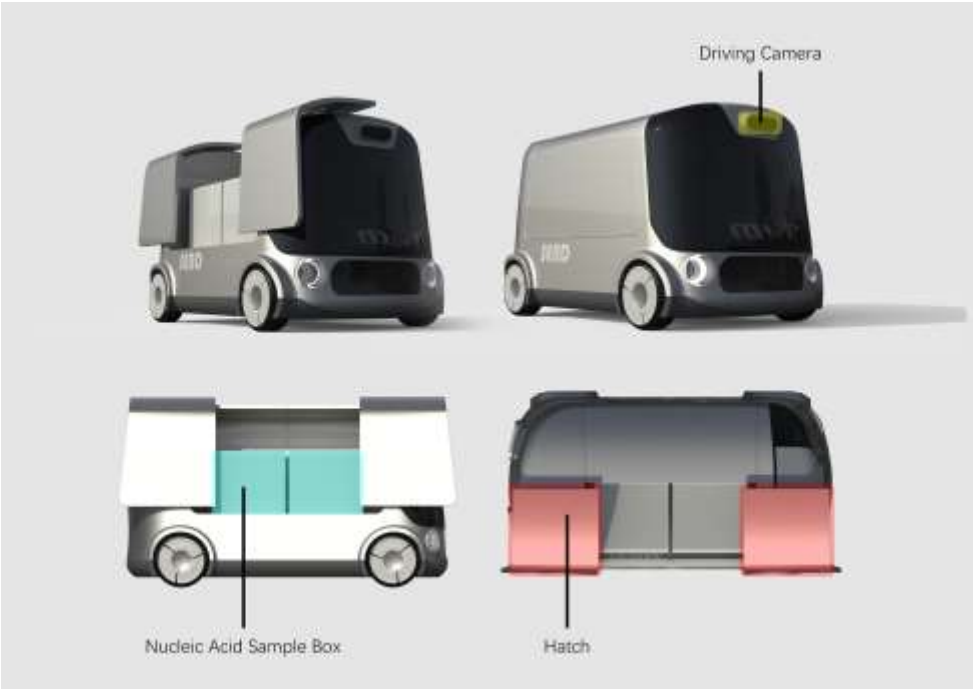

Fig. 10: Mobile robot vehicle

Forest Chemicals Review
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The community-based self-help nucleic acid testing model was developed after reviewing related previous research studies and taking the ERG theory into account to identify the need for community-based self-help nucleic acid testing, as shown in Figure 11. The test results are then sent to the mobile phone app of the individual who provided the sample after the processing of the test is completed, and the hospital will provide medical intervention if the individual tests positive for COVID-19.

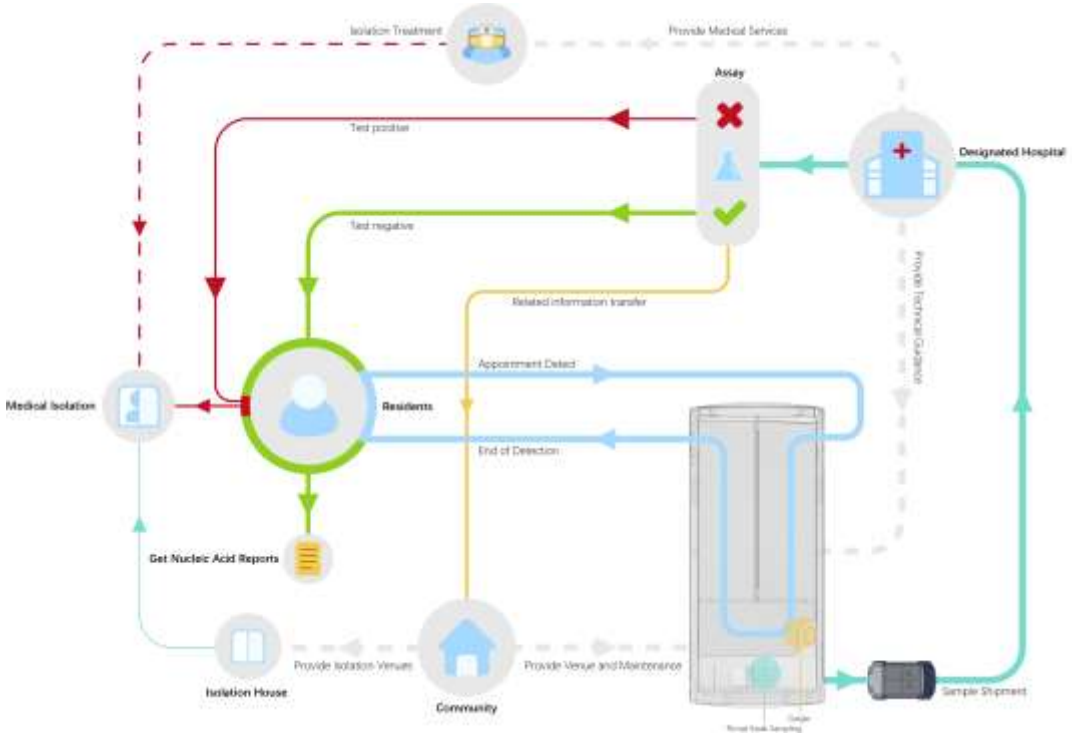

Fig 11: Community-based self-help nucleic acid testing system

III. CONCLUSION

The purpose of this study is to respond to the normalisation of COVID-19 by proposing services and related means for community residents to easily and quickly perform nucleic acid testing which would determine whether they test positive or negative for the virus, and also to reduce the workload and shortage of medical personnel and facilities that are otherwise required to take and process a large number of nucleic acid tests. and that community-based self-help nucleic acid testing has a better preventive effect than centralised nucleic acid testing after an outbreak, which is one of the reasons why the majority of the community residents in this study feel that there is the need for this service. In this study, the needs for nucleic acid testing are determined based on the ERG theory by conducting field research in three local communities in China. As such, the actual needs of nucleic acid testing are determined, and the needs are coded and categorised based on the grounded theory. The significance of the different needs are validated through a factor analysis, and finally, a service structure model is proposed for community-based self-help testing and the means of such testing.

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The information obtained from the research study is also examined to understand the specific needs around current community-based nucleic acid testing services in China. The results of the subsequent questionnaire and the factor analysis of the data are statistically significant, thus demonstrating the validity of the results of this study. Finally, social work done at the micro and macro levels can be linked. This means that social epidemiology, disease prevention and health promotion can all be used to deal with major and critical health issues through multiple perspectives and approaches, promote health equity and provide holistic methods to address community health issues.

As with many studies, this study has its limitations. The communities studied are limited to one city in China, so future studies can examine other communities or countries and survey or review their work and findings. Nevertheless, the results of this study can act as a reference source for improving existing nucleic acid testing models.

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